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Authoring Tools and Methods for Adaptive Training and Education in Support of the US Army Learning Model: Research Outline

**by Scott Ososky, Robert Sottilare, Keith Brawner,
Rodney Long, and Arthur Graesser**

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14. ABSTRACT While human tutoring and mentoring are common teaching tools, current US Army standards for training and education are group instruction and classroom training, also known as one-to-many instruction. Recently, the US Army has placed significant emphasis on self-regulated learning (SRL) methods to augment institutional training where Soldiers will be largely responsible for managing their own learning. In support of the US Army Learning Model and to provide affordable, tailored SRL training and educational capabilities for the US Army, the US Army Research Laboratory is investigating and developing adaptive tools and methods to largely automate the authoring (creation), delivery of instruction, and evaluation of computer-regulated training and education capabilities. A major goal within this research program is to reduce the time and skill required to author, deliver, and evaluate adaptive technologies to make them usable by a larger segment of the training and educational community. This research includes 6 interdependent research vectors: individual learner and unit modeling, instructional management principles, domain modeling, authoring tools and methods, architecture, and evaluation tools and methods. This report (1 of 6 interdependent research outlines) focuses on research to reduce the time and skills required to author adaptive instruction with the goal of guiding learning in militarily relevant training and educational domains.					
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Preface

This report is 1 of 6 interdependent research outlines in the Adaptive Training research program. Portions of this text, which originated in ARL-SR-0325,¹ appear in all 6 reports to ensure that readers get the same cross-cutting information.

¹ Sottilare R, Sinatra A, Boyce M, Graesser A. Domain modeling for adaptive training and education in support of the US army learning model—research outline. Aberdeen Proving Ground (MD): Army Research Laboratory (US); June 2015. Report No.: ARL-SR-0325.

1. Introduction

Training and education tools and methods must be of sufficient intelligence to understand the needs of individual learners and units of learners, to mitigate negative learner states, and to guide and tailor instruction in real time to optimize learning. These tools and methods must also be affordable, effective, and easy to access and use. These requirements are enablers of the US Army Learning Model (ALM), which includes an emphasis on self-regulated learning (SRL) where Soldiers are expected to manage their own learning and career development through the growth of metacognitive (e.g., reflection), self-assessment, and motivational skills (Butler and Winne 1995). While SRL skills are difficult to train and develop, support may be provided to the learner through “adaptive training technologies” (tools and methods), which may be focused to guide learning and reinforce SRL principles.

To support ALM, the US Army Research Laboratory (ARL) has developed a program of research called “adaptive training”, which includes 6 interdependent research areas or vectors: individual learner and unit modeling, instructional management principles, domain modeling, authoring tools and methods, evaluation tools and methods, and architectural and ontological support for adaptive training. The reports documenting these vectors expand the scope of the adaptive tutoring research described in ARL-SR-0284 (Sotilare 2013) to support ALM requirements in the mid- and long-term evolution of training and educational technology: the Synthetic Training Environment and the Future Holistic Training Environment for Live and Synthetic.

This report (1 of 6 interdependent research outlines) focuses on research to reduce the time and skills required to author adaptive training and education content in a variety of militarily relevant domains. Today, most intelligent tutoring systems (ITSs), a form of adaptive training tool to support one-to-one computer-based instruction, support well-defined domains in mathematics and physics. Since Soldiers operate in more complex, dynamic, and ill-defined domains, it is necessary to expand the scope of adaptive training tools and methods to support training and education in these militarily relevant domains, including team training. In turn, the process by which intelligent tutors are currently authored for complex domains is time intensive, requiring a degree of skill similar to those in computer programming. The authoring tools and methods research vector examines the various tools, processes, and technologies that enable adaptive tutor creation, including 1) software interfaces for sequencing content, defining instructional techniques, strategies and tactics, and integrating disparate systems,

2) the creation and management of instructional content (i.e., content management systems and reusable learning objects), and 3) algorithms that provide for semi- or fully automated content creation with significantly reduced human input.

2. Research Goals and Objectives

The goal of the research described in this report is to reduce the time and skill required to author adaptive instruction. The authoring tools and methods research vector is concerned with the creation and management of various resources required to support adaptive instruction within an ITS or a series of ITSs. This report outlines research objectives intended to provide guidelines, methods, tools, and/or technologies in service of the stated research goals. The primary objectives of this research are intended to provide guidelines, best practices, tools, models, and methods in support of this research goal:

- For human authoring: Apply usability heuristics to develop best practices to guide authoring of adaptive systems based on the author's role (e.g., domain expert, instructional designer, or course manager).
- For computer-aided authoring: Identify elements of the authoring process that are candidates for automated or semi-automated authoring processes to remove the human from the authoring process wherever possible.
- For leveraging existing training and educational capabilities: Establish standards for the integration of functionally disparate tools and technologies (e.g., external training systems and serious games) that may be relevant to adaptive systems to reduce the need for authoring.

This report examines the background and requirements for authoring adaptive training and educational capabilities in different domains along with research challenges, dimensions of authoring, desired end states, and interdependencies with other adaptive training research vectors.

3. Background

While human tutoring and mentoring are common teaching tools, current US Army standards for training and education are group instruction and classroom training—also known as one-to-many instruction. Group instruction and classroom training have been generally focused on acquiring and applying knowledge in proxies for live training environments (e.g., desktop simulations, virtual simulations, constructive simulations, and serious games).

Classroom training, especially for complex topics, is often taught as a series of lists that the instructor goes through in a linear fashion (Schneider et al. 2013). This approach puts a heavy burden on the learner to build mental models and make conceptual connections. Using this instructional methodology may lead to varying degrees of success due to individual differences in skills, traits, and/or preferences. Alternatively, adaptive training can support those individual differences in learners; however, the burden to adapt and tailor instruction shifts to the author (who may also be a course manager, course developer, domain expert, or instructor) to build mental models of adaptive training components, the relationships between the components, and the processes (e.g., workflow) by which robust tutors are created. For nonautomated authoring tasks, the creation and use of these mental models are among the primary research challenges.

Small group instruction in live environments has also been used to assess application of knowledge and the development of skills. A standard feedback mechanism for US Army training is the after-action review (AAR) where significant decision points and actions are captured for small group discussion that is conducted after the completion of a training event to help capture teachable moments and to aid Soldiers in reflecting on their recent training experiences.

Both classroom training and small group instruction are manpower intensive, requiring teachers, mentors, and support staff to guide the Soldier's experience. Today, ITSs primarily guide learner training and education for cognitive tasks in well-defined domains (e.g., problem solving and decision-making tasks in mathematics and physics). Soldiers tend to perform cognitive, affective, psychomotor, and social tasks in both well-defined (e.g., building clearing) and ill-defined domains (e.g., leadership, resource allocation). ITSs generally provide static training (e.g., sitting at a desktop computer to train on a serious game) that falls short in matching the dynamic nature of many US Army operational tasks (e.g., psychomotor tasks), thereby reducing opportunities to develop and transfer skills to the operational environment.

Research is needed to understand the characteristics, similarities, and differences of US Army training domains (i.e., cognitive, affective, psychomotor, social, and hybrid) to develop efficient and effective adaptive training and educational tools and methods that support SRL in complex, ill-defined, and physically dynamic military domains.

3.1 Self-Regulated Learning and the US Army Learning Model

In 2011, the US Army placed significant emphasis on the development of SRL skills with the expectation that new methods of instruction (e.g., ITSs) would

augment institutional training (i.e., classroom and small group instruction). One-to-one human tutoring has been shown to be significantly more effective than one-to-many instructional methods (e.g., traditional classroom instruction: Bloom 1984; VanLehn 2011). However, it is neither practical nor affordable to have one expert human tutor to mentor each Soldier in the US Army for every required operational task. This alone signals the need for capabilities to support one-to-one tailored training and educational experiences.

Additionally, under the ALM, Soldiers are largely responsible for managing their own learning, but SRL skills are difficult to train and develop (Butler and Winne 1995; Azevedo et al. 2009; Graesser and McNamara 2010). We anticipate adaptive training tools and methods will fill this gap and will provide personalized guidance to acquire, apply, retain, and transfer knowledge and skills to the operational environment. This signals the need for a computer-regulated learning strategy to augment missing SRL skills; however, adaptive training technologies must first become affordable, sufficiently adaptive, and easy to use for this strategy to be realized.

3.2 Motivation for Research

A promising alternative to one-to-one human tutoring is one-to-one adaptive training tools that include ITSs. Meta-analyses and reviews support the claim that ITS technologies routinely improve learning over classroom teaching, reading texts, and/or other traditional learning methods. These meta-analyses normally report effect sizes (sigma [σ]), which refers to the difference between the ITS condition and a control condition in standard deviation units. The reported meta-analyses show positive effect sizes that vary from $\sigma = 0.05$ (Dynarsky et al. 2007) to $\sigma = 1.08$ (Dodds and Fletcher 2004), but most hover between $\sigma = 0.40$ and $\sigma = 0.80$ (Fletcher 2003; VanLehn 2011; Graesser et al. 2012; Steenbergen-Hu and Cooper 2013, 2014; Ma et al. in press). Our current best meta-meta estimate from all of these meta-analyses is $\sigma = 0.60$. This performance is comparable to human tutoring, which varies from between $\sigma = 0.20$ and $\sigma = 1.00$ (Cohen et al. 1982; Graesser et al. 2011), depending on the expertise of the tutor. Human tutors have not varied greatly from ITSs in direct comparisons between ITS and trained human tutors (VanLehn et al. 2007; VanLehn 2011; Olney et al. 2012).

Graesser et al. (2015, in press) are convinced that some subject matters will show higher effect sizes than others when comparing any intervention (e.g., computer trainers, human tutors, group learning) to a control. It is difficult to obtain high-effect sizes for literacy and numeracy because these skills are ubiquitous in everyday life and habits are automatized. For example, Ritter et al. (2007)

reported that the Cognitive Tutor for mathematics has shown an effect size of $\sigma = 0.30\text{--}0.40$ in environments with minimal control over instructors. Human interventions to improve basic reading skills typically report an effect size of $\sigma = 0.20$. In contrast, when the student starts essentially from ground zero, such as many subject matters in science and technology, then effect sizes are expected to be more robust. ITSs show effect sizes of $\sigma = 0.60\text{--}2.00$ in the subject areas of physics (VanLehn et al. 2005; VanLehn 2011), computer literacy (Graesser et al. 2004; Graesser et al. 2012), biology (Olney et al. 2012), and scientific reasoning (Millis et al. 2011; Halpern et al. 2012). As a notable example, the Digital Tutor (Fletcher and Morrison 2012) improves information technology by an effect size as high as $\sigma = 3.70$ for knowledge and $\sigma = 1.10$ for skills. The effect size attributed to improved instruction and improved domain knowledge has not been separated in this analysis. Such large effect sizes would never be expected in basic literacy and numeracy.

Overall, these are promising results and equate to an increase of about a letter grade improvement over traditional classroom instruction. While ITSs are a promising technology to support adaptive training for individuals in well-defined domains like mathematics, physics, and computer programming, the US Army requires the ability to develop and exercise Soldier skills in more ill-defined domains (e.g., leadership) and at the unit level (e.g., collaborative learning and team training). Developing and maintaining the ability to make effective decisions under stress and in complex environments is also desirable.

Adaptive systems by their nature require additional content and complexity to support tailored learning for each user and, as a consequence, have a very high development cost, a major barrier to adoption by the US Army. Adaptive systems are also insufficiently adaptive to support tailored self-regulated training and educational experiences across a broad spectrum of military tasks as required by the ALM. Today, few ITS authoring tools are generalized across all of the domains requiring training, and no evaluation criteria or standards have been developed to promote reuse and interoperability among ITSs (Sottilare et al. 2012b). In other words, current adaptive systems are not yet intelligent enough to support the tailored instruction required by the US Army in the breadth of domains being trained; but there is a stable foundation of 50 years of science on which to grow an adaptive training and education capability for the US Army.

3.3 Adaptive Training and Education Definitions

In support of the ALM and affordable adaptive training and educational capabilities for the US Army, ARL is investigating and developing adaptive tools

and methods. A desired end state is the automation of authoring (creation) processes, instruction, and evaluation of computer-regulated training and education capabilities to help build SRL skills and support mixed-initiative interaction. A major goal within this research program is to reduce the time/cost and knowledge/skill required to author, deliver, and evaluate adaptive technologies to make them usable by a larger segment of the US Army training and educational community.

Adaptive training and education research includes elements of adaptive tutoring, distributed learning, virtual humans, and training effectiveness evaluation. For additional detail on research specific to ITSs, refer to ARL-SR-0284 (Sotilare 2013). Definitions are provided for this section to distinguish between adaptive training and education elements and also to highlight their relationships:

- **Adaptive Tutoring:** Also known as intelligent tutoring; tailored instructional methods to provide one-to-one and one-to-many computer-guided experiences focused on optimizing learning, comprehension, performance, retention, reasoning, and transfer of knowledge and acquired skills to the operational environment.
- **Adaptive Tutoring Systems:** Also known as ITSs; the mechanism or technologies (tools and methods) to provide tailored training and educational experiences. Adaptive tutoring systems respond to changing states in the learner and changing conditions in the training environment to optimize learning. Adaptive tutoring systems anticipate and recognize teachable moments.
- **Virtual Humans:** Artificially intelligent visual representations of people that simulate or emulate cognitive, affective, physical, and social processes.
- **Distributed Learning:** Concurrent distribution of training and educational content to multiple users at the point of need in which content is intelligently selected to support learning, increased performance, and long-term competency in selected domains.
- **Training/Learning Effectiveness:** Evaluation of the impact of training and educational tools and methods on usability, learning, comprehension, performance, retention, reasoning, and transfer of knowledge and acquired skills to the operational environment.
- **Adaptive Training and Education Systems:** A convergence of ITSs and external training and education capabilities (e.g., serious games, virtual

humans, simulations) to support engaging experiences with reduced need for authoring (Sottilare 2015).

- **Generalized Intelligent Framework for Tutoring (GIFT)** (Sottilare et al. 2012a; Sottilare et al. 2013): An open-source, modular architecture whose goals are to reduce the cost and skill required for authoring adaptive training and educational systems, to automate instructional delivery and management, and to develop and standardize tools for the evaluation of adaptive training and educational technologies.

Adaptive training and education research at ARL is being conducted across 6 interdependent research vectors: individual learner and unit modeling; instructional management principles; domain modeling, authoring tools and methods; evaluation tools and methods; and architectural and ontological support. This report (1 of 6 interdependent research outlines) focuses on authoring tools research for adaptive training systems with the goal of guiding learning in militarily relevant training and educational domains.

Soldiers operate in a variety of complex, dynamic, ill-defined domains where their ability to persevere in the face of adversity, adapt to their situation, collaborate, and think critically are key to the successful completion of their assigned missions. To develop and exercise these skills, it is paramount for Soldiers to train in challenging environments. Presently, these few challenging training environments have been largely provided through manpower-intensive methods or systems with little ability to adapt instruction to support their learning needs. To illustrate this point, Franke (2011) asserts that through the use of case study examples, instruction can provide the pedagogical foundation for decision making under uncertainty. However, this approach is limited in implementation by the expanse of potential cases that would need to be consistently updated and maintained to support large populations like the US Army.

As noted previously, adaptive systems like ITSs have been shown to be effective in promoting learning in primarily static (e.g., learners seated at desktop computers) instructional settings within relatively simple, well-defined domains (e.g., mathematics, physics) for individual learners. For our purposes, static instruction includes cognitive, affective, or social training tasks where a desktop computer delivers instruction and where the physical movement of the learner is limited to activities that can be conducted while seated. For example, static instruction can effectively support cognitive tasks involving decision making and problem solving but are less effective for training tasks involving motion and perception (e.g., land navigation and marksmanship). Ideally, we desire portable adaptive instructional capabilities to go with Soldiers to support training and

education at their point of need across a wide spectrum of US Army operational tasks. Research is needed to develop tools and methods to support broader domain modeling, which is representative of the full spectrum of US Army operational tasks. Standards, interoperability, and automation (e.g., automated scenario generation) (Zook et al. 2012) will likely play a significant role in making adaptive training practical. In this way adaptive training technologies will have the greatest impact on organizational learning in the US Army.

3.4 State of the Art in Authoring Tools and Methods

While positive and significant gains have been made to adaptive tutor authoring tools and technologies, progress is often measured in point-solutions and limited in cross-domain applicability. A number of significant challenges exist within tutor authoring.

First, given the current state of the art, it is estimated that 1 h of training requires between 10 and 100+ h of development, at an estimated cost of \$10,000 per hour of training (Sottilare and Brawner 2014). Where authoring systems are concerned, tradeoffs are often made between functionality and generalizability. For instance, adaptive tutoring content can be authored for well-structured domains (e.g., math, physics) using relatively stable authoring tools specifically tailored to said content, but these tools fall short in ill-defined domains, including those complex domains that are relevant to Army training objectives (e.g., decision making, leadership, teamwork). It logically follows that authoring content for Army-relevant skills and tasks would currently require even more time and money to author, given the current state of the art. Therefore, as advances are made in the parallel areas of domain modeling, learner modeling, and instructional management, so too are tools needed to leverage outputs from those areas to author content for ill-defined, complex domains.

Second, the domain of adaptive tutor authoring is still in its infancy; as such, there is a general lack of standardization between tools and methods (workflow) for authoring such content. While ITS and traditional computer-based training (CBT) bear some superficial similarities in delivery and presentation, the complexity of authoring adaptive tutoring is many orders of magnitude greater because of the inclusion of learner modeling, pedagogical agents, complex configuration, and content creation. Further, the skill of authoring adaptive tutors represents a relatively new interaction paradigm. The authoring process might share processes associated with other content creation activities, such as assembling a slide deck, designing a blog post, or sequencing an interactive narrative (such as a video game). Though, none of the aforementioned activities represent a one-to-one

mapping with authoring adaptive tutors. It is a new form of content creation and an activity that is yet to be fully defined. Thus, potential authors must form new mental models regarding the creation of adaptive tutors by integrating new knowledge with existing mental models of activities that are perceived to be similar. The authoring vector will support users in constructing rich and accurate mental models of tutor authoring.

Third, the manner in which adaptive tutors will interoperate with external systems is currently piecemeal, implemented on a case-by-case basis, which further complicates the authoring process and serves as a threat to the generalizability of adaptive authoring systems. GIFT, for instance, is a framework; it is intended to be interoperable with a variety of external programs and technologies. In practice, separate communication pipelines are required for each specific application.

Further, these pipelines provide inconsistent functionality with respect to the type of data that can be exchanged between GIFT and the application; thus, the communication and configuration options that are available to tutor creators will also vary wildly. Interoperability with existing simulators' authoring environments, content management, and assessment engines is a significant threat to a consistent authoring experience, the root cause of which may lie beyond the scope of this vector. For instance, the modeling, simulation, and training industry is far larger in size and scope than the ITS industry. As a by-product, efforts to synchronize the modeling and simulation community with the needs of the ITS community have languished (Stottler et al. 2005) because, in part, developmental order often favors a simulation first and instructional system second approach. Those authoring concerns are not limited to training applications. A fully realized, generalizable authoring system will also need to be able to interface with content management systems, learner databases, social media frameworks, and (eventually) intelligent agents. As those capabilities are enabled by the architecture, research will be required to define authoring requirements in interacting with those supporting components.

3.5 Overview of GIFT Authoring Tools

GIFT is described as “an empirically-based, service-oriented framework of tools, methods and standards to make it easier to author computer-based tutoring systems (CBTS), manage instruction and assess the effect of CBTS, components and methodologies” (Sottilare et al. 2012a). As GIFT is simultaneously a research project and open-source application, it is in continuous development and includes a number of technologies, features, and tools targeted toward a variety of users, including instructional designers, researchers, and students. For instance, the

framework incorporates models of domain content, pedagogical methods, sensor data processing, interoperability with external applications, and learners, each with its own module and/or configuration. As such, it is important to recognize that GIFT is not simply a set of authoring tools; however, research issues related to authoring are part of the focus of the current program plan and the explicit focus of this report.

Until recently, GIFT applications were created by writing and/or editing eXtensible Markup Language (XML). One “tutor” was, in reality, a series of separately configured but inter-reliant components. Directly editing the files was a complex process that required users to understand how to properly write encoded XML. XML editing programs were created to make its editing easier, but this did not alleviate users’ need to understand how the various components of GIFT interact with one another at the system level. By comparison, the current stable versions of GIFT (2014-2 and 2015-1) provide some browser-based interfaces to facilitate semi-automated user creation of the XML output; these interfaces take the first steps toward unifying a diverse set of authoring tools behind a consistent user interaction experience. However, the current implementation of the graphical-user interfaces does not change the requirement that authors must understand the system-level conceptual model of GIFT. In this report we propose research that will result in interfaces that help to close the gap between an author’s mental model of adaptive tutor creation and the system-level conceptual model of GIFT.

Sottilare (2013) outlined goals for GIFT, including the following authoring-related goals: decrease the effort required for authoring (time, cost, etc.), decrease the skill threshold required to author adaptive tutoring, support users in organizing knowledge, support pedagogical design, allow for rapid prototyping of adaptive tutoring, leverage standards for integration of external media and applications, and promote content reuse. The authoring goals for GIFT are concurrent with authoring goals for ITS, in general, which endeavor to support training and education requirements outlined in the ALM.

4. US Army Requirements for Adaptive Training Systems and Authoring

The Army Science and Technology community uses Warfighter Outcomes (WFOs) as the authoritative source for identifying Warfighter needs. WFOs are used to share research and future technology solutions. In the training and education domain, the adaptive training and education research program is targeting 4 specific requirements to support the evolution of US Army training:

adaptive training and education systems; big data; training at the point of need; and artificial intelligence.

4.1 Adaptive Training and Education Systems and Authoring

The primary gap to be addressed under this Army requirement is the lack of adaptive systems (e.g., intelligent tutors) to support individual and collective (team or unit) training. The Army needs an adaptive training and education capability that is persistent and easy to use/access with minimal start-up time. There are also requirements to automate an informal AAR (also known as post-exercise critique) to reduce the time and skills needed to produce the AAR and improve its focus and quality. Another line of thought also notes that the artificial intelligence in ITSs could be used to facilitate rapid mission planning and course-of-action analyses as a job aid in operational contexts.

The major connection between the adaptive training and education requirement and the authoring tools and methods research vector is the need to extend authoring capabilities in 2 directions. The first of these directions relies upon the enabling of the authoring of feedback for AAR in complex domains or in the rapid authoring of correct assessment models within simplistic domains. The second of these directions relies upon the automation and magnification of the authoring process through extensive reuse, content readability by computerized process, and the configuration of the system to meet the needs of the learner.

4.2 Big Data and Authoring

The primary gap to be addressed under this US Army requirement is that there is a lack of capability to handle and process large amounts of structured and unstructured data (also referred to as big data). One capability needed is a structured data analytics program linking individual data (e.g., achievements) to required long-term competencies in military occupational specialties (MOSSs). This would allow Soldiers to understand where they rank in terms of experiences and achievements among other Soldiers in their MOS. It would also allow the US Army to identify specific experiences among successful Soldiers in that MOS and provide a model for other Soldiers in that MOS to follow. The data could also be used by course managers and instructors to continuously improve instruction and the mental models of both human and computer-based instructors. Finally, data collected on trainee learning and performance during adaptive training experiences could be used to facilitate Unit Training Management where unit commanders would have access to empirical data to support unit training decisions.

The major connection between the Army's big data requirement and authoring tools is ability to collect or generate learner data from content interactions, content data for machine traversal, and training environment data to make the connection among learner behaviors, instructional tactics, and their varying degrees of effectiveness given instructional context (existing conditions). This will allow course managers to be aided by machine techniques of content creation and to see the effectiveness of their authored material.

4.3 Training at the Point of Need and Authoring

The primary gap to be addressed under this US Army requirement is the lack of an easily accessible, persistent, cost-effective, and low-overhead training environment. A capability is needed to bring training to Soldiers instead of Soldiers going to fixed training locations. This point-of-need training capability would be easily distributed, web based, and built upon an open-enterprise architecture in the cloud. US Army training and educational opportunities would be available on demand anywhere and anytime. However, the delivery mechanism (e.g., laptop computer, mobile device, and smart glasses) for adaptive training is critical in determining the limitations of the domain model scope and complexity. For example, it may be extremely difficult to train all the complexities of a psychomotor task in a desktop computer setting.

The major connection between point-of-need training and authoring relies upon the practicality of extending adaptive training beyond the desktop. This is primarily an architectural content conversion process, avoiding the work of making multiple complete instances of content (web, mobile, desktop, smart glasses, etc.). Training content (e.g., instructional content, assessments, feedback) should be able to be reworked into the appropriate format.

4.4 Artificial Intelligence (AI) Capabilities and Authoring

The primary gap to be addressed under this US Army requirement is that the US Army lacks an automated capability to replicate the complexity and uncertainty of the operational environment. This gap specifically points to the lack of adaptiveness in virtual humans, intelligent tutoring systems, and other training capabilities. This gap leads to Soldiers developing training-response strategies that result in less challenging training over time along with lower engagement and lower levels of learning and transfer of skills to more challenging operational environments.

The major connection between AI capabilities and authoring involves the discovery and innovation of techniques to support computer-aided authoring.

Computer-aided authoring comes in a few differing types, from automated scenario evolution, to automated question and hint generation, to intelligent content search and retrieval. By implementing such concepts with AI support, the authoring burden for instructors and course managers developing highly complex training and educational domains may be reduced.

AI capabilities, domain modeling, and authoring involve the discovery and innovation of techniques to support a concept called “automated scenario evolution” being developed by Sottilare (2015). AI capabilities are needed to support automated scenario evolution where AI drives the generation of new “child” scenarios from a single-parent scenario based on dimensions of that scenario and the state of the trainee. In this way, the authoring burden for highly complex training and educational domains may be reduced.

For example, consider a single scenario where dimensions include variable challenge levels based on 3 threats (i.e., low, moderate, high), 3 types of field of view (i.e., narrow, moderate, and wide), and clear line of sight (i.e., near, moderate, and far). AI could spawn 27 new child scenarios based on combinations of these variables. This requirement is closely linked to adaptive training capabilities described in Section 4.1 of this report, and the realization of this capability will enable the development of affordable self-authoring adaptive systems. Through this capability, complex domains may be modeled for adaptive training systems without the need for long development cycles or special authoring skill sets.

5. Understanding the Dimensions of Authoring

There are 4 typical elements that compose ITSs, a prime example of an adaptive training and education system: a learner or trainee model, an instructional or pedagogical model, a domain model, and some type of user interface. The domain model typically includes an expert or ideal student model by which the adaptive system measures/compares/contrasts the progress of the learner toward learning objectives. The domain model also includes the training environment, the training task, and all of the associated instructional actions (e.g., feedback, questions, hints, pumps, and prompts) that could possibly be delivered by the adaptive system for that particular training domain. Typical interaction among the learner, the training environment, and the adaptive system (tutoring agents) is shown in Fig. 1.

Typical training systems examine the interaction between the learner and the training environment to measure progress toward learning objectives. The learner acts on the environment (e.g., opens a door or makes a choice to move into the

room or stay outside) and then observes any changes or reactions within the environment. Adaptive systems add a layer of software-based tutoring agents that are designed to guide the learner in much the same way as a human tutor interacts with a learner. The tutoring agents observe the behaviors of the learner to assess their states (e.g., performance and attitudes) and interact with the learner to provide support, direction, and instruction. In addition, they track the effect of interactions on learning. Tutoring agents also interact with the training environment and may manipulate the environment to present more challenging or less challenging scenarios in response to the assessed state of the learner.

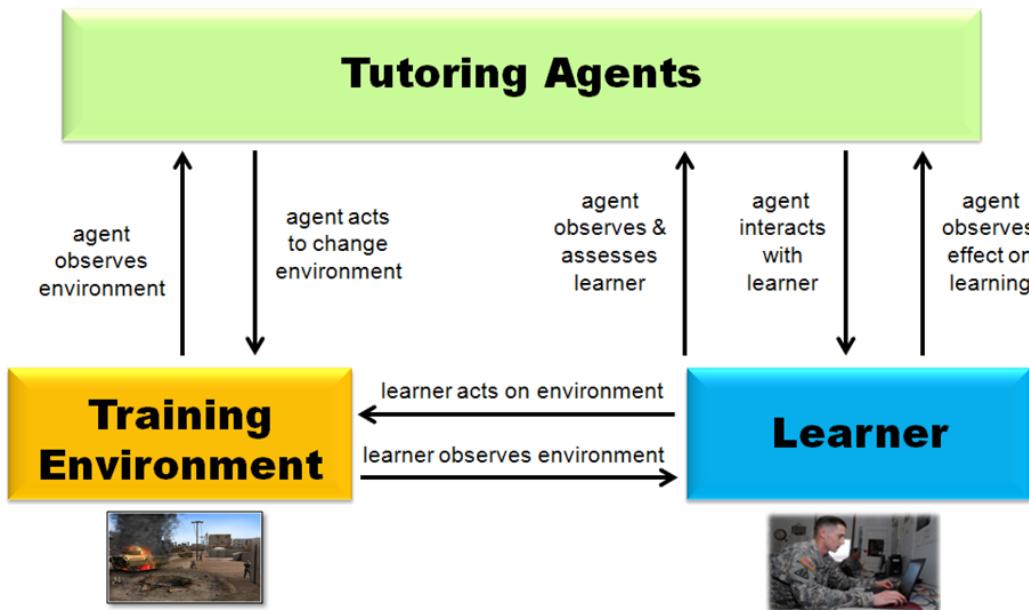


Fig. 1 Adaptive training interaction

Authoring is an element of the ITS, which is not overtly visible in Fig. 1, but it potentially interacts with and/or influences each of the other elements within the tutor. Authoring identifies, for example, what is observed, how an agent interacts, and why it selects certain interaction strategies over others. In practice, the authoring element requires input from many dimensions: the ability to configure each of the other ITS elements (including external training environments), a mechanism to incorporate new components and configurations into the ITS, and significant human capital (at least for the near future) to help shape the tutor, manipulate its many configurations, and harness its output. These dimensions are described in greater detail below.

The widespread adoption of adaptive tutoring will require authoring systems that are easy to use and contain the functionality needed to support a wide variety of training tasks and environments. Murray (2003) described the current state of

adaptive tutor authoring as a series of tradeoffs between usability, depth, and flexibility. Given the depth and flexibility required to author for the complex domains associated with Army training objectives, the current authoring process is complicated, requiring a degree of skill similar to that of computer programming.

Mental models will serve as the underlying theory for the user-centered research component of this outline (described in Section 6.1). Rouse and Morris (1986) explained that mental models “are the mechanisms whereby humans are able to generate descriptions of purpose and form, explanations of system functioning and observed system states, and predictions of future states” (p. 7). Mental models influence users’ expectations regarding a system’s functionality and guide user interaction behavior (Ososky 2013). An individual’s mental model regarding a particular system is influenced by past experiences and perceived similarity of other systems to the target system. Further, human mental models do not need to be complete or even accurate to be applied to a specific system interaction (Norman 1986).

Therefore, to increase the usability of authoring tools, it first is necessary to identify and describe authors’ mental models for authoring tools. Potential authors, however, may enter into an interaction with authoring tools with a variety of backgrounds, including instructional design, training facilitation, and subject matter expertise. It is likely that each user group will reveal a mental model for interacting with authoring tools, which is significantly different from the others. It is important to acknowledge the distinction between user groups because those models are likely to be (even more) different from the manner in which the authoring system is actually designed. This is because engineers have their own mental models about how authoring tools should work, and they use this model to develop the realized version of the system (Streitz 1988). The engineer’s or designer’s model has been referred to as the conceptual model (Norman 1983).

Stated differently, users may know (in their minds) what type of adaptive content they need to author but are unable to leverage the authoring system to achieve their goals. Thus, a gap exists between user intent and system usability. Likewise, the more that is assumed about how users may interact with authoring tools, the larger this gap is likely to be. Norman (1986) described this gap as the gulfs of execution and evaluation. The gap between user intent and system representation was expressed as 2 gulfs because there are 2 ways to close the gap. Users can adapt their plans to the design of the system (e.g., acquire new knowledge of a complex system), or the system’s interface can be improved to match the needs of the user (e.g., leverage familiar terms and interaction elements). For adaptive tutor authoring tools, it will likely be necessary to approach this gap from both sides.

6. Authoring Research Goals and Challenges

A foundational goal of adaptive training and education research at ARL is to model the perception, judgment, and behaviors of expert human tutors to support practical, effective, and affordable learning experiences guided by computer-based agents. To this end, and in support of the authoring goals stated earlier, the following 4 primary challenges for authoring adaptive systems have been identified and are described in this section.

- Describe human mental models and define authoring interaction paradigms.
- Identify candidates for automated authoring and develop processes to reduce the human authoring workload.
- Extend authoring capabilities to support integration with existing training and educational technologies (e.g., training simulations, simulators, and serious game platforms).
- Enable collaborative authoring.

6.1 Describe Human Mental Models and Define Authoring Interaction Paradigms

Stated previously, authoring adaptive tutoring content represents a new interaction paradigm. Further, tradeoffs are made in authoring between usability, depth, and flexibility. The purpose of this subtask is to attend to the usability component of the current state of the art. The end goal of this subtask is to reduce the time and skill required to author adaptive tutoring content.

Designing an interface to support the creation of adaptive tutors is a nontrivial task and one that is not quite like many other superficially similar tasks (e.g., creating slides, creating a web page, or designing a video game). Many potential users may not even fully realize the benefits that adaptive tutoring can provide over traditional classroom or CBT. Further, there may be multiple user groups that may be interested in creating adaptive tutors, and each of these user groups has their own sets of knowledge and interaction expectations. For instance, we can theoretically identify potential authors from instructional designers, subject matter experts, and researchers, respectively, but do they need to be regarded as different types of users for the authoring system?

Therefore, the research approach will examine the design of authoring tools from both sides of the system usability gap. We intend to conduct user research to illustrate the various mental models of adaptive tutor design, as well as non-

system-specific goals of those potential users. We will leverage users' goals, desires, and intentions to drive the requirements for the design of a prototype authoring tool interface for GIFT. Outputs from this research will also help to identify differences in the needs, if any, between each user group. Research activities may include, but are not limited to, interviews, surveys, and direct/indirect observation. Authoring tools will be evaluated along dimensions of utility ("Does the system support users' goals?"), usability ("Can the user easily accomplish their goals?"), and the time to author an hour of adaptive course content.

It is unlikely, at least in the near term, that it will be possible to design-out all of the complexity of authoring an adaptive tutor. We must strive for a reasonable balance in the tradeoffs between usability, depth, and flexibility. To that end, users may need to learn about concepts that are unique to ITS in order to develop new skills and knowledge that will enable users to design effective tutors (for a discussion of automated authoring, see Section 3.2). To that end, we propose to examine the system side of the usability gap as well. Currently, GIFT is composed of a rudimentary set of GUI-based authoring tools defined by system-level terminology and theoretical ITS components. We will conduct research that will examine conceptual models of tutor authoring with the goal of improving the ease of learning of terminology and components associated with ITS. In service of this objective, we will survey the waterfront of existing authoring tools and technologies to identify themes in authoring components and terminology, as well as present suggestions for improvements upon the current workflow. The outputs from this research are expected to produce guidelines and best practices that could be used to drive the establishments of standards in the field of adaptive tutoring.

Continuous improvement of prototype authoring interfaces and interaction paradigms is the final cornerstone of our proposed research approach. We will track the progress of the authoring system after the bridge has been built from both sides of the gap. We intend to develop and implement tools that will manually and automatically collect data with respect to the use of and experience with GIFT authoring tools. Research activities may include, but are not limited to, website metrics (in the case of cloud-based authoring tools), remote unattended usability testing, and collection of qualitative user experience feedback via the authoring system or GIFT community forum channels.

6.2 Identify Candidates for Automated Authoring and Develop Processes to Reduce the Human Authoring Workload

The process of building a tutor is more involved than the creation and customization of its various component parts. Many of these component parts will not require authoring for the average user. As an example, the pedagogical method of instruction from one domain of instruction to another should remain mostly the same. The same may be said of the methods of modeling the learner, or of the sensors used. Having an authoring system that makes extensive use of default settings (or preconfigured sets of settings) allows the individual tutor author to focus on the domain of instruction.

In regards to the domain of instruction, the basic process is to 1) gather content, 2) make the content available, 3) customize it to suit the individual needs of the audience, 4) generate tutoring information, 5) perform the delivery of the content for informational and practice settings, and 6) take traditional ITS actions (e.g., model the learner, select from content, track learner experience) (Olney et al. 2015).

Currently, the first step of authoring (content gathering) is typically performed as a series of searches via a search engine. Modern search engines perform many of the functions behind this content gathering automatically (utilizing search history, individual profiles, etc.) in an effort to improve search results. If available content were already indexed according to keywords and learning objectives, it is conceivable that this process may be automated (Jesukiewicz and Rehak 2011; GooruLearning 2014).

The actions of indexing this content for availability, such as tagging the content with metadata, can be performed in an automated fashion with today's cutting-edge technology (Veden 2015), which is an architecturally assisted process discussed in another research vector. If this content is text related, simple tutoring information, such as hint/prompt/pump generation, can be performed in a machine-assisted manner (Olney et al. 2012).

Indexed and actionable content, hosted in a repository, can be traversed through a machine-assisted process in accordance with the learner model. As an example, content for a highly motivated and experienced learner could be queried from a content provisioning system with descriptors of the context needed for the individual (Ray et al. 2014). Such a provisioning system would be able to match the learner to content based on his/her personal traits and the individual content attributes (e.g., subject matter, difficulty level, user ratings). A learner can progress

through a learning path planned by the pedagogical system, taking prescribed pedagogical actions, such as hint giving, because of their pregenerated nature.

The system above describes a process of automating the process of authoring and automatically building an appropriate course, using up-to-date and reusable learning objects (RLOs) created and curated in a centralized repository. Portions of such a system exist through pedagogical recommendation engines, such as the eMAP (Goldberg et al. 2012), content curation systems, such as Nuxeo (Nuxeo Platform 2015), exchange languages, such as xAPI (Regan 2013), and 3QL (Ray et al. 2014), and others. However, research is needed to support the tie-in, integration, testing, effectiveness, and accuracy of such an automated system.

6.3 Extend Authoring Capabilities to Support Integration with Existing Training and Educational Technologies

The development of an ITS is expensive, labor intensive, and requires highly skilled personnel from a variety of disciplines. One way to reduce the time and cost of development is to encourage reuse through the use of standards for processes, tools, and software components. Templates for domain models and learning content could also reduce costs (Sottilare 2014). Content Management Systems (CMSs), for example, can be used to reduce costs by supporting learning content reuse. However, it is time consuming to upload content, and typically, metadata is manually input by administrative personnel, reducing the effectiveness of search and retrieval tools. Research continues in automating the process of analyzing documents to decompose them into RLOs and generate accurate metadata. Data analytics is another method that may be used to provide a smart search capability for a CMS. Current research is also exploring “best practices” for the use of RLOs to include the use of assessments. Social media may also provide a crowd-sourced capability in the generation of learning content, as well as vetting current learning content/courses.

In adaptive training environments, virtual humans can be used as virtual instructors (e.g., talking heads) to help guide the learner through a training session. Nonplayer Characters can also be used to support training scenarios that require human interaction. GIFT provides the Media Semantic character set to support the use of commercial virtual humans. Further research is required to ease the authoring process for the creation and management of virtual humans within adaptive tutoring environments.

Another challenge is to improve/standardize authoring support for external training applications (e.g., the integration of ITSs with simulations or game-based training environments). The Game-based Architecture for Mentor-Enhanced

Training Environments (GAMETE) is one example. GAMETE is focused on allowing training developers to add an intelligent tutoring capability into a game-based simulation environment (Engimann et al. 2014). Automated scenario generation (Zook et al. 2012) is another area of interest, as is authoring support for tutors intended for units, teams, and teams of teams.

In addition to the areas discussed above, research is needed to determine optimal methods for authoring:

- Techniques, strategies, and tactics within GIFT
- Performance and competency assessments within GIFT
- Domain content and expert model development
- New content and instructional models from existing data sources

6.4 Enable Collaborative Authoring

It is envisioned that, in many cases, a team of individuals will be developing a course; those individuals will have differing responsibilities. As an example, one individual may create a pre-/posttest while another may put together lectures, another may design practice scenarios, and yet another may review/test the completed course for quality assurance. Beyond the user experience concerns for individual authoring discussed in the previous section, there are a number of follow-on issues that will need to be addressed to enable collaborative authoring. As a simple example, content permissions need to be implemented that allow the appropriate individuals (or groups) to have access to different components, keep items restricted from general users, prevent overwriting of changes from unauthorized users, and provide a functional baseline for quality testing. This research subtask will examine issues related to collaborative authoring, including implementation, compatibility, and exporting.

6.4.1 Web Authoring

In GIFT's desktop implementation, authors can create their own questions, surveys, and survey contexts using the Survey Authoring System. All of the questions that have been created and included in GIFT's baseline are available to all GIFT users. Once an individual creates his/her own surveys and questions, that content stays local to the user's own desktop version unless he/she exports and then imports the survey to another individual's version of GIFT. In the development of a web-based version of the Survey Authoring System, consideration will need to be given to where content created by an individual user is stored and whether it is included in the survey bank for all to use. This creates a

unique problem, as instructors who may be using GIFT to create and administer tests likely will not want their assessments and questions (and answers) readily available to other individuals and students.

To address the storage and availability of content authored by specific individuals, research and thought will need to be put into permissions and storage. The survey authoring system in particular will likely need to only provide the stored content to the individual that created it and anyone working on the research/authoring team. Consideration will need to be given to the new challenges that develop from moving the authoring tools to a web environment. Development will be needed to address the traditional problems of sharing, access, and editing.

6.4.2 Versioning and Compatibility

It is very important that created content is backward compatible with previous versions of GIFT. Individuals may invest a large amount of time in developing a course in a specific version of GIFT and may resist moving to a newer version if their content will not be compatible. In a desktop implementation they can continue using their previous version; however, in a web-based implementation, this backward compatibility has greater importance. Web-based implementations do not necessarily allow for the functionality of “snapshotting” a course in order to maintain an existing version.

Furthermore, there is an importance on optional updates of course material. As an example, if a resource used within a course has been updated by a third party, the course author should have the capability (but not the necessity) to update that course to use the new object. Such updates should not be mandatory, as the course author should have the opportunity to review the material prior to delivering it to students from a shared web-enabled environment.

6.4.3 Sharing and Exporting Tutors

In addition to collaborative authoring, it is logical to assume that authors will want to share their created tutors with schoolhouses and/or learners. GIFT currently has 2 procedures to share courses: either 1) the export of a course where it is presumed that the receiving GIFT user has a full installation GIFT software and third-party applications or 2) to export a course with an entire install of GIFT, resulting in a relatively large software package (500 MB). There are 2 concerns in this area that require further attention: 1) examination of the export package for more efficient distribution and 2) how to handle configuration errors when the receiving user is missing required hardware or software components. These issues are applicable even within a cloud-based implementation of GIFT.

7. Interdependencies with Other Adaptive Training Research Vectors

This section examines interdependencies between authoring and the other 5 adaptive training research vectors (Fig. 2). This discussion forms the basis for the sequencing of research and ultimately bringing adaptive training capabilities into a state of practice.

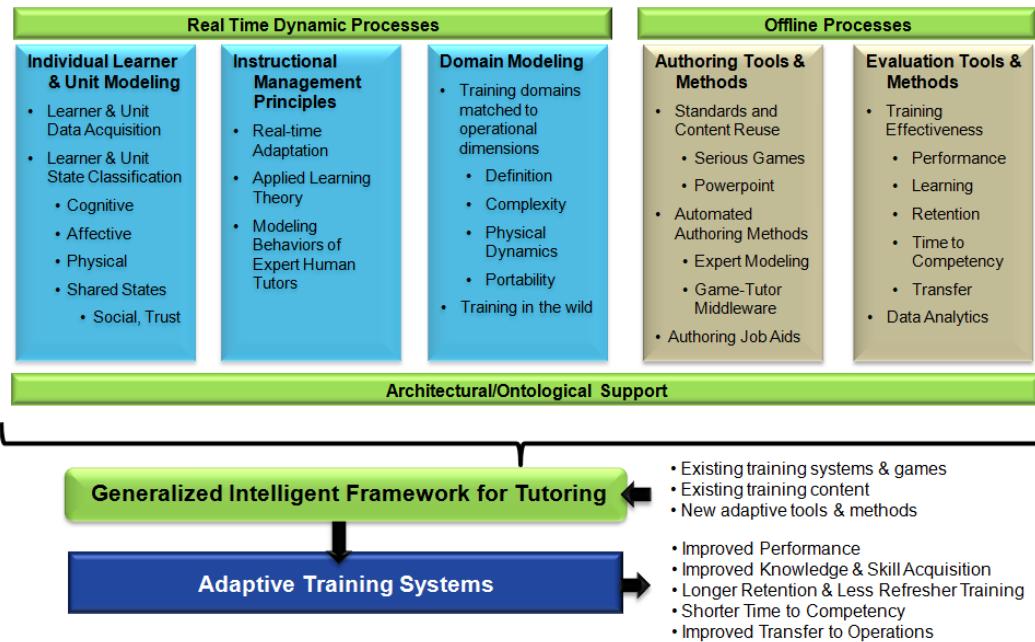


Fig. 2 Adaptive training research vectors

Authoring tools and technologies enable the selection and configuration of learner models, instructional pedagogy, domain content, and evaluation metrics, respectively. Conversely, the products and insights generated from each of the other vectors provide guidance to the requirements for the authoring experience. Finally, reusable content and automated authoring rely upon architecture to fully realize those capabilities.

7.1 Learner Modeling and Authoring

With respect to authoring, tutor creators will require guidance and tools to select and configure the appropriate dimensions of a learner model for a given course. This might require the content creator to select a subset of data points from a larger long-term learner record and/or integrate new attributes into the model. Likewise, authors will need to be able to specify where and how these data are used within the tutor, as well as how to add the data back into a long-term learner record store upon completion of the course. Accurate modeling of the learner is

critical to driving instructional decisions in adaptive training systems, but research is needed to determine what this dataset will look like. Candidates abound in the literature, but in general, these include transient data/states, cumulative states (building over time), and enduring data/states (Panева 2006). Transient measures of importance include individual behavioral and physiological data, and cognitive, affective, physical, and social states to represent learning. Cumulative measures include achievements (e.g., certifications, training, education, and experiences), affiliations, work history, and domain competency. More enduring information about the learner might include gender, culture, first language, physical constraints (e.g., colorblind/deaf), values, personality attributes, or other trait-based information (Sottilare and Brawner 2014). All of these measures/states are potential drivers for adaptive training decisions. Authoring support for learner modeling may take the form of useful user interfaces, semi-automated configuration support, and connection gateways to external learner database systems. Philosophically, an author should have to author items related to the assessment of student knowledge and experiences, but the individual differences, states, and trait information should be abstracted away from their use in nonresearch settings.

7.2 Automated Instruction and Authoring

Authoring will work with the instructional management vector to outline the author's role in instructional management. Specifically, we will work to determine what level of control is appropriate with respect to authoring instructional strategies. We will receive the outputs of the instructional management vector to determine how to design the authoring interaction for the management and selection of content appropriate to a chosen instructional strategy (e.g., Merrill's component display theory, Gagne's 9 events of instruction). The instructional management and authoring vectors will also collaborate on larger, cross-vector issues, including the design of adaptive tutoring for teams. Generally, the goal is not to involve automated instruction in the authoring process; philosophically, the content author or subject matter expert should only require knowledge of a domain, while the system should know best how to instruct it. If any authoring decisions are involved, they should be limited to a specific subset of available models, with default values well informed from the state of practice.

7.3 Domain Modeling and Authoring

With respect to domain modeling, authoring knowledge representations for purposes of intelligent tutoring is a significant challenge within the current

iteration of the GIFT authoring tools, with the authoring and domain modeling groups being tightly linked. We will exchange data and information with the domain modeling vector to synchronize author requirements for domain modeling, determine the level of transparency of the domain modeling process to the end user, and develop user interfaces for modeling knowledge, feedback, and other instructional interventions. This will be performed with an emphasis toward the automation of items that can be automated, or with an emphasis toward mental models where the author must be involved.

7.4 Evaluation and Authoring

Training effectiveness is concerned with the impact of training on learning, retention, and transfer. Outputs of training effectiveness research will specify methods for measuring, analyzing, and instantiating instructional strategies across different training domains and team configurations. In practice, these measures may take the form of data hooks that will be built into the tutor to facilitate automated data collection for either real-time or posttraining analysis. There is likely to be considerable overlap between the data needs of training effectiveness and those of the tutor itself. Therefore, there exists an opportunity to take advantage of these overlaps in the specification of semi-automated and automated authoring interfaces, leading to a more robust authoring suite, thus reducing the time and resources required to develop a complete tutoring solution for a given domain. Data hooks for the automated conduct of authoring studies should be developed and used in the same fashion as many of the web-based services now commercially available. While not expressly a research task, the task of developing new mental models to support new types of system authoring is a research task that will be informed through these now-traditional methods.

7.5 Architecture and Authoring

The Architecture vector interacts with each of the other vectors, including Authoring. Architecture and Authoring will work together to close the gap between the user mental model and the system conceptual model—Authoring will provide guidelines for the design of the authoring tool interface and the overall user experience. The authoring and architecture group are tightly linked in the same manner as the authoring and domain modeling group; one relies upon the user mental model, while the other relies upon the computerized content model. Architecture will specify the technologies for which user experiences are required, and both teams will work together to bring new functionality online, including social media integration, reusable components, and content management systems. Finally, it is expected that Architecture will enable greater

automation of adaptive tutoring content over time, which will require parallel development in the authoring experience.

8. Conclusions

This report outlines ARL's plans for conducting research in adaptive training and education to support the ALM (US Army Training and Doctrine Command 2011). Specifically, this report relates to research and prototype development of authoring tools and methods. We seek to the answer to the question, What adaptive training methods provide the best value (in terms of effectiveness and affordability) for the authoring of US Army Training and Education tutoring domains?

This report outlined the following research goals:

- [For human authoring]: Apply usability heuristics to develop best practices to guide authoring of adaptive systems based on the author's role (e.g., domain expert, instructional designer, or course manager).
- [For computer-aided authoring]: Identify elements of the authoring process that are candidates for automated or semi-automated authoring processes to remove the human from the authoring process wherever possible.
- [For leveraging existing training and educational capabilities]: Establish standards for the integration of functionally disparate tools and technologies (e.g., external training systems and serious games) that may be relevant to adaptive systems to reduce the need for authoring.

These research goals, in turn, support the following goals of the authoring vector:

- Decrease the resources (time, cost, etc.) required to author an intelligent tutor.
- Decrease the skill threshold required by various user groups associated with authoring and managing an intelligent tutor.
- Enable rapid prototyping of intelligent tutors for rapid design and evaluation of capabilities.
- Develop standards, including common tools and interfaces, for tutor authoring.
- Promote reuse of content, modules, and data structures in tutors.

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List of Symbols, Abbreviations, and Acronyms

AAR	after-action review
AI	artificial intelligence
ALM	US Army Learning Model
ARL	US Army Research Laboratory
CBT	computer-based training
CBTS	computer-based tutoring systems
CMS	Content Management System
GAMETE	Game-based Architecture for Mentor-Enhanced Training Environments
GIFT	Generalized Intelligent Framework for Tutoring
ITS	intelligent tutoring system
MOS	military occupational specialty
RLO	reusable learning object
SRL	self-regulated learning
WFO	Warfighter Outcome
XML	eXtensible Markup Language

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